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ABSTRACT

In an effort to gain an overview of the application of computer technology in education and training, to identify areas requiring additional research, and to identify potential application areas for use in technical training, field visits were made to representative military and civilian institutions which are using the computer in instructional programs. A review of the recent research literature and computer equipment manufacturers' technical data was also conducted. The primary focus of the study was on the terminal devices available for use in a training system and on the software required for effective use of a computer in a training environment. Several computer terminals used in computer assisted instruction (CAI) are discussed and computer-controlled audio presentation is described. Programing languages which have been used in CAI are categorized into four groups: general-purpose problem languages, extended problem languages, interactive terminal problem languages, and author-student problem-oriented languages. A typical language from each category is examined. On the basis of their survey, the authors make some suggestions regarding terminal devices, programing languages, and areas for further research. (JY)

AFHRL-TR-70-24

AIR FORCE HUMAN RESOURCES LABORATORY

APPLICATION OF COMPUTERS IN EDUCATIONAL AND TRAINING SYSTEMS: A SURVEY OF COMPUTER-ASSISTED INSTRUCTIONAL CENTERS

By

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TECHNICAL TRAINING DIVISION
Lowry Air Force Base, Colorado

December 1970

AIR FORCE SYSTEMS COMMAND

BROOKS AIR FORCE BASE, TEXAS

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FOREWORD

This report documents the initial efforts of the Technical Training Division of the Air Force Human Resources Laboratory to assess the state of the art in the application of computer technology in the educational and training process.

The authors wish to thank the personnel at the educational research centers visited for their cooperation and assistance in supplying information for this report. Thanks should also go to the computer equipment manufacturers who provided the technical data used.

Every effort has been made to provide accurate information in the areas reviewed; however, in a field as complex and dynamic as the use of computers in instruction, the information reported remains current for only a very short period. Any references to a specific computer system or component for illustrative purposes should not be construed to infer a recommendation of that item.

This research was accomplished under Project 1121, Technical Training Development; Task 112102, Application of Computers in Air Force Educational and Training Systems. Dr. Marty R. Rockway was the project and task scientist.

This report has been reviewed and is approved.

George K. Patterson, Colonel, USAF
Commander

ABSTRACT

This paper presents an overview of representative centers active in the research, development, and application of the computer in education and training. Field visits were made to military and civilian agencies in order to obtain a cross-section of various types of applications and research projects. The information presented is based on the field visits and the most recent reports available on the activities of the various centers. Computer terminals used in computer-assisted instruction are discussed, and computer-controlled audio presentation is described. Programming languages which have been used in computer-assisted instruction are categorized, and a typical language from each category is examined.

SUMMARY

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Objectives

The objectives of this study were (*a*) to provide an overview of the application of computer technology in the educational and training process, (*b*) to identify areas requiring additional research, and (*c*) to identify potential application areas for use in technical training.

Approach

Field visits were made to representative military and civilian institutions using the computer in the instructional process. A review of research literature and computer equipment manufacturers' technical data was also conducted.

Conclusions

In addition to the overview provided by the field visits, the primary focus of the study was on the terminal devices available for use in a training system and the software required for effective use of a computer in a training environment. The following conclusions were reached in these areas:

1. A large number of new lower cost terminal devices are currently available and appear to have potential for use in a technical training system.

2. Hardware interface for analog-digital applications can be simplified through use of small low-cost processors of the mini-computer type.

3. Use of mini-computer interface expands the range of mainframe processors suitable for use in training applications and provides greater flexibility for interfacing of nonstandard input/output devices.

4. Software for use in instructional systems should be designed to provide maximum flexibility in use of all types of input/output devices.

5. Course writing languages must provide author support for on-line data entry.

6. Course authors should have minimal constraint in developing, testing, and implementing a wide variety of instructional strategies.

This summary was prepared by G. S. Walker and E. M. Gardner, Technical Training Division, Air Force Human Resources Laboratory.

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EXPLANATION OF TERMS

ADC - Analog to Digital Converter. Converts analog voltages to some binary number of corresponding magnitude.

Alphameric terminal. A device which can display letters and numbers, but no graphic or photographic information.

ASCII - American Standard Code of Information Interchange. A type of binary encoding used to represent characters sent over telephone or telegraph lines.

Audio response unit. A computer peripheral which stores words or phrases of human speech on a drum or disk device which allows the words to be retained and played, possibly to several people simultaneously, under computer control.

BCD - Binary Coded Decimal. An alternative 6-bit code for encoding characters. Allows 64 characters to be represented. Commonly used on second generation computers.

CAT - Computer-Administered Testing. The presentation and collection of answers to questions presented on a computer-controlled terminal device.

Computation. Performance of mathematical processes using the computer as a calculator.

Computer-managed instruction. Use of the computer to aid the instructor in guiding the student through the instructional process and in scheduling his academic activity.

CRT - Cathrode Ray Tube Display Unit. A device whose display is on a phosphor coated evacuated tube of the type used in television receivers.

Cursor. A movable point of light giving visual indication of a point which is being referenced on a screen.

DAC - Digital to Analog Converter. Converts binary numbers to some analog voltage of corresponding magnitude.

Data channel. A device which reads from or writes data into core memory of a computer. Typically connects peripherals to mainframe of computer.

Dataphone. A Bell System device which allows direct connection of teletype compatible equipment to a telephone line without an acoustic coupler.

Delta modulation. The process of representing the magnitude of an analog signal by periodic statement of its relative change in value since the last sample rather than by periodic statement of its absolute magnitude.

Drill and practice. Use of the computer to guide, control, and monitor by repetition of a specific task or set of tasks.

DVST - Direct View Storage Tube. A phosphor screen storage device which stores its display as an internal static charge in the tube. Contents stored are viewed directly as points of light on screen.

EBCDIC - Extended Binary Coded Decimal Interchange Code. An alternative 8-bit code for encoding characters. Allows 256 characters to be represented. Commonly used on third generation computers.

Emulation. The process of duplicating the input-ouput response pattern of a hardware device by means of other hardware which interprets some and duplicates other parts of the emulated system.

Graphic tablet. A two-dimensioned surface and a light pen type device which inputs the location of the pen on the surface to the computer.

Graphic terminal. A terminal which can display not only letters and numbers, but also lines and figures which can be composed of illuminated lines and points.

Joy-stick. A lever controlled input device which is used to position a cursor on a graphic display screen.

Light pen. A probe device which is touched to a screen in order to select a point on the screen. The selected point is conveyed to the computer to which the probe is attached.

Logical problem solving. Use of the computer for performing a series of computations necessary to arrive at a solution to a problem.

Mainframe. The processor, channels, core memory, and control unit of the computer. Does not include peripherals.

Mini-computer. A class of small primarily arithmetic processors addressing no more than 32,000 16-bit words and accessing a limited number of larger peripherals. Can usually be connected to larger processors and often interface between large systems and various slower or non-standard devices. Priced normally less than $15,000, as low as $4,000.

MODEM - Modulator-demodulator. A device to encode binary computer information into audio information to be transmitted over telephone lines. Usually a higher-speed more complex device than an acoustic coupler.

Mouse. A graphic input device in which the device is rolled around on a plane surface to position a pointer on cursor on a graphic display screen.

Multiplexer. An electronic device used to pack data from several slow devices into a single high-speed telephone line. Reduces line cost when several devices are to be communicating with the same computer since one high speed line is cheaper than all of the individual lines which would have to be used if no multiplexer were available.

Peripherals. Input and output devices attached to the mainframe for information transfer and storage. Typically, tape, bulk-storage, card reader, line printer, communications handler.

Simulation. The process of duplicating the input-output response patterns of a hardware device by means of a software program designed to interpret input to the simulated system in a manner analogous to the hardware being simulated.

Simulation and gaming. A model of a real life situation represented by a given set of circumstances and parameters stored in the computer.

Telecommunications (teleprocessing). Connection of peripherals to a remotely located mainframe over telephone lines of some type. A MODEM is normally required for connection.

Time-sharing. A simulated environment in which each of several users is allowed access to a single computer and is generally unable to distinguish any interactions of the system with other uses.

Tutorial dialog. A technique based upon interaction between the student and the computer in which the response of the computer varies to fit the individual characteristics displayed by the student.

Video (photographic) terminal. A terminal which can display information with varying gray tones such as photographs, graphic, and alphameric information.

APPLICATION OF COMPUTERS IN EDUCATIONAL AND TRAINING SYSTEMS: A SURVEY OF COMPUTER-ASSISTED INSTRUCTIONAL CENTERS

I. INTRODUCTION

Purpose

The purpose of this report is to document the initial efforts of the Technical Training Division to explore the application of computers as an aid in the instructional process. The use of the computer in an instructional system appears to have long-range potential when selectively applied to Air Force technical training.

This report is part of the preliminary research required to develop the selection criteria for a multi-media computer-based instructional system. The system should be capable of providing a research tool for exploration of the various instructional strategies available in a computer-based system controlling, or used in conjunction with, other instructional media. Development of this system is a part of the Air Force advanced development program "Innovation in Training and Education." Unit B of the program calls for the development of a functional prototype of an advanced instructional system. The system will be designed to integrate computer-assisted instruction, automated training, and audio-visual displays with information handling techniques all controlled by a computer.

Most applications of the computer as a tool to aid in the instructional process can be categorized as Computer-Assisted Instruction (CAI) or Computer-Managed Instruction (CMI). CAI generally involves the computer as an active element in the learning process, thereby providing some type of man-machine interaction. CMI is an aid to the instructor in guiding the student through the instructional process. The computer monitors the student's progress through his materials but does not interact directly with the student. These general categories of applications, combined with an appropriate audio-visual presentation system and management information system, will form a part of the prototype advanced instructional system.

Background

The Air Force used computers in training for the Semi-Automatic Ground Environment System (SAGE) in 1955. The system provided automated on-the-job training via simulation. An updated version of the training is currently in use with the Back-Up Interceptor Control System (BUIC). The Air Force has also sponsored CAI research on the Socrates system developed in 1963 by Bolt, Beranek and Newman. The system used a Digital Equipment Corporation PDP-1 computer with on-line typewriters and auxiliary drum storage. Applications were made to electronic troubleshooting, medical diagnosis, and accounting, (Feurzeig, 1964).

Since 1967, the Air Force has also jointly sponsored research by the System Development Corporation on development of a natural-language capability for CAI.

Currently, the Air Force is field testing a computer-directed training subsystem developed by the System Development Corporation for use on base-level Burroughs B-3500 computers. This system is designed to interact with the user by means of a remote keyboard/printer device which sends or receives one line of data at a time. The system is not designed to control any other on-line display devices at the present time. Two courses have been developed for use on the system, a B-3500 Computer Operator CAI course and a course on Operation of the Base-Level Military Personnel System. The CAI system is programmed in an adaptation of System Development Corporation's PLANIT CAI language. The system has been designed to meet a variety of training needs, but the current course material is primarily for on-the-job training. Another on-the-job training application of computers was developed in 1966 on a limited basis for Intelligence Training on use of the formatted file system for intelligence data retrieval. The project developed and tested the course at the Intelligence Data Handling System Directorate, Headquarters, Continental Air Defense, Colorado Springs, Colorado. The system, although not currently in use, did demonstrate that CAI could be effectively used for on-the-job training in an operational environment.

Method

Field visits were made to representative educational and training research centers using the computer as a tool in aiding the instructional process. These centers were selected to get as broad a cross section as possible of the hardware, software, and instructional applications. The visits

provided current information on the various projects and also established communications for future exchange of information.

A review of the most current literature on the use of computers in training was conducted to provide a background on the system requirements for educational use. Computer manufacturers' brochures and equipment specifications were also used to determine the status of computer technology relative to possible use in a computer-based training system.

In addition to describing the activities of the research centers visited, this report examines two of the most critical factors in the development of a computer-based training system: (*a*) computer terminal devices and (*b*) computer languages used in instructional systems.

II. DISCUSSION

Field Visits

The information presented in this section is based on observations and documentations obtained during field visits conducted from November 1969 through May 1970. The visits provided an up-to-date assessment of the field and an in-depth understanding of the problems associated with the varied applications and systems observed. A summary of the activities of each of the research centers visited is presented in the order that the visits were made.

Florida State University Computer-Assisted Instruction Center

Since 1964, Florida State University (FSU) has had an active program for research, development, and operation of computer-assisted instruction. Starting with one terminal in 1965, the center now has an IBM 1500 CAI Instructional System. This system operates 32 cathode ray tube (CRT) terminals which have both light pen and keyboard response devices. The system also has a telecommunications capability supported by a DEC 680 switching system controlled by a PDP-8 computer. This system supports eight teletype terminals located in the Wakulla County schools, approximately 20 miles from FSU. These terminals are used by elementary and junior high school students for reading, mathematics, and oral language CAI materials. The FSU center has developed its own Data Analysis and Management System for the 1500 CAI system. Lack of a suitable data reduction and analysis capability for use by faculty and students doing educational research made it necessary for them to provide their own software capability. Efforts are also being made to integrate the CAI software with the data management system to provide an operating system for CAI research. Work has also been done to extend the research capabilities of various CAI languages such as COURSEWRITER II, BASIC, APL, and FOCAL.

The hardware system approach at FSU has been toward small dedicated CAI systems such as the Digital Equipment Corporation PDP-8 TSS and the IBM 1500 CAI system. This approach may prove to be the only practical cost-effective way CAI can be introduced in the near future on a broad scale. The introduction of so-called mini-computers with low-cost time-sharing capabilities and CAI software may be the beginning of the technological breakthrough required to broaden the implementation of CAI.

In addition to computer systems development, FSU is working on the following CAI research topics (Hansen, O'Neil, Brown, Rivers, & King, 1970):

> (1) Identification of those instructional processes and learning behaviors which we most efficiently optimize by computer support, (2) investigation of appropriate instructional strategies that implement optimal learning, (3) investigation of learner strategies as they are revealed within CAI training systems, and (4) investigation of the reliability, effectiveness, and validity of each new computer-based instructional activity (e.g., computer-managed instruction).

The FSU center also assists in CAI curricula development for use in university courses. The center also provides instructional services to other colleges and public schools. An undergraduate CAI course in physics which had been offered in the past for credit provided excellent results with test-review exercises. It is planned to continue to use the test-review exercises and to expand the problem solving units as a service function.

A partial list of projects illustrates the variety and scope of the research program conducted by the FSU CAI center (Hansen *et al.*, 1970):

1. Social Science Information Retrieval.
2. A Rural County Computer Related Instructional Technology Project.
3. The Mediated Transfer of Words.
4. Preventative Maintenance Systems.

5. Learner Control in Automated Instruction.
6. Effects of Memory Support on Anxiety and Performance in Computer-Assisted Learning.
7. Development of a Dynamic Decision Model for CAI Utilizing Regression Analysis Techniques.
8. An Investigation into the Effects of Retention on Differential Feedback Delay Intervals.
9. Effect of Sex and Stress on State Anxiety and Peformance in Computer-Assisted Learning.

This brief summary of activities of the CAI center at FSU demonstrates the potential for both the research and the service function of a relatively small yet effectively managed computer system.

Human Resources Research Organization

Project IMPACT is an advanced development project sponsored by the United States Army and conducted by the Human Resources Research Organization (HumRRO). IMPACT is an acronym for *I*nstructional *M*odel *P*rototype *A*ttainable in *C*omputer *T*raining. The project is designed to

> . . . . provide the Army an effective, efficient, and economical computer-administered instruction system. The objective is to (*a*) develop two generations of a prototype CAI system with (*b*) accompanying prototype multipath (branching), individualized programs of instruction.
>
> The system of instruction is to be capable of adapting to the capabilities and characteristics of each individual trainee. This adaptiveness will be based both on the "entry characteristics" of the trainee and on his long term and immediate response patterns within the course, so that each step in the instruction will be fitted directly to his needs at that point in the instructional process. The instruction will also be made directly relevant to his specific job requirements (Seidel, 1969).

One of the most important aspects of the project is the design and development of the Instructional Decision Model (IDM). The model is to be a set of rules for "matching presentation of specific content (selecting and sequencing) with trainee capabilitites (student characteristics and responses to earlier material)." The development concept of IMPACT requires the testing of a series of IDM iterations to develop the most effective model for a given training situation. The concept of the instructional model in the IMPACT project is that of "an open information-exchange system, in which there is continual interaction between the student and his environment, and in which the effective environment for the student changes with continued experiences (Seidel, 1969)."

The project's current computer system is an IBM 360 Model 40 with 256 bytes of core storage, an IBM 2314 disk drive, four 2401-5 tape drives, a 1403 N1 printer, a 2540 card reader/punch, a 2501 reader, and three 1050 typewriters (one remotely located). Of special interest are the 12 student terminals which contain a CRT display with light pen, keyboard, visual display (rear projection) capable of presenting material in still or motion picture form, and an electronic (Sylvania) tablet that permits a somewhat stylized hand-written input to the computer.

The software efforts in this project have been directed toward the expansion of the IBM COURSEWRITER III CAI language. A list processing capability has been added and another modification allows the use of CRT terminals over telephone lines at any distance from the central processing unit.

Efforts are also being made to establish criteria for design of a CAI language that would be largely independent of the computer system on which it is used.

A CAI course in COBOL Computer Programming is being developed as the initial instructional material to be implemented. The course content is based on a field survey and task analysis of the job functions of COBOL programmers in the Army.

Project IMPACT is an excellent example of the type of interdisciplinary approach required in CAI system development. The staff is composed of behavioral scientists, mathematicians, engineers, instructional programmers, and computer software programmers. Progress in this complex developmental effort has been substantial and should produce an optimal CAI system suitable for large-scale implementation.

The University of Illinois Computer-Based Education Research Laboratory

One of the oldest CAI research facilities was established in 1959 at the University of Illinois under the PLATO program. PLATO is an acronym for *P*rogrammed *L*ogic for *A*utomatic *T*eaching *O*perations. The PLATO system has grown from a single terminal connected to an ILLIAC I computer to 20 graphic pictorial terminals driven by a Control Data Corporation 1604 computer.

In 1963, a development effort was started on a low-cost, interactive graphic terminal combined with a random-access image selector. The terminal is based on the use of a plasma display panel which is under development at the University of Illinois. It is hoped that the panel which has the properties of memory, display, and high brightness can be produced commercially at low cost. The panel itself is a thin glass structure filled with gas cells that are capable of being selectively ignited under control of the computer. Production of a low-cost student terminal with the characteristics of a plasma-type terminal will constitute a major cost breakthrough in the development of economically viable computerized instruction. The possibilities of a large-scale application of computer-based education have been summarized as follows:

1. Gradual abolishment of lock-step schedules and narrowly specified curricula in formal education. Students could proceed at a pace determined by their own capacity and motivation.
2. Provision of remedial instruction or tutorial assistance during regularly scheduled courses for students with insufficient preparation.
3. Reduction in the number of large lecture classes at the college level, in favor of small instructional groupings and seminars.
4. Special instruction at home for physically handicapped students.
5. Development of arithmetical or other skills, at the elementary level, away from the exposed and often competitive environment of the classroom.
6. Effective job training or retraining for any employee group especially affected by expanding technology.
7. Continuing education for professional personnel, permitting the updating of knowledge and skills in their own offices and on their own schedules (Alpert & Bitzer, 1969).

Some of the areas in which course material has been presented have been electrical engineering, geometry, biology, nursing, library science, pharmacology, chemistry, algebra, math drill, computer programming, and foreign languages. In presenting these materials, a wide range of computer application modes have been used ranging from drill and practice to student-directed inquiry. The use of the inquiry mode is an extension of the tutorial made. This method allows the student to control his interaction with the system, investigate, and gather additional information to solve a problem presented to him by the computer. This mode has been used very effectively in medical science, engineering, and physical science presentations.

In evaluating the educational effectiveness of the PLATO system, the relatively small sample sizes involved in the experimental studies preclude attaining results considered as definitive. Alpert and Bitzer do, however, present the following conclusions:

1. That computer-based education is a plausible approach to improved individualized instruction in a very wide array of courses or subject material areas.
2. That the nature of educational testing and evaluation calls for and will be radically and substantially affected by the availability of large computer-based education systems; a valid measure of effectiveness calls for a much larger sampling of data and a larger period of comparison than has heretofore been available (Alpert & Bitzer, 1969).

The PLATO program as it has evolved through three systems (PLATO I, II, and III) has been one of the few that have included an effective research and development program on all aspects of computerized instruction. This effort has involved innovations in computer hardware and software as well as course materials and modes of application.

University of California at Santa Barbara Computer Center

The Computer Center at The University of California at Santa Barbara (UCSB) installed an IBM 360 Model 50 in 1966 to implement an advanced instructional and research system. Display consoles were placed in five departments for use in a variety of courses including chemistry, calculus, electrical engineering, sociology, economics, and psychology.

The system uses a display console based on a Tektronix Direct View Storage Tube (DVST) and a double keyboard separated into an operator or program control keyboard and an operational keyboard with an alphanumeric capability. The unit provides an excellent alphanumeric and graphic display. The console, called Teleputer, was marketed commercially by Bolt, Beranek and Newman. The system is a time-shared, on-line, interactive computational application based on a technique called on-line computation developed by Dr. Glen J. Culler and Dr. Burton D. Fried.

The system is an excellent example of the potential of an interactive problem-oriented language used with a large-scale time-sharing computer. The system has evolved from the IBM 360 Model 50 through and IBM 360 Model 65 and now is based on an IBM 360 Model 75. The 2075 central processing unit has 500K bytes of core storage and two million bytes of Large Capacity Storage (LCS), four 2311 disk drives, one 2314 disk drive, two 1403 printers, two 2401 tape

drives, one 1402 card reader/punch, and 60 teleputer consoles, 45 located on the UCSB campus and 15 at other locations across the country.

In January 1970, the National Science Foundation announced an experimental program to explore the use of the UCSB on-line system in undergraduate instruction in chemistry. Students at UCSB and nine other institutions will use the system for problem solving. An earlier experiment at UCSB showed that use of the system in teaching chemistry allowed the students to discover for themselves properties of model chemical systems. Through use of the on-line system and related teaching techniques, it is hoped to greatly improve instruction to the point that first and second year students will understand concepts at a senior and graduate student level.

The UCSB on-line system operates in a time-sharing mode and allows use of the computer system for processing batched programs for research and other university use.

Naval Personnel and Training Research Laboratory, San Diego, California

Since 1967, the Computer-Assisted Instruction Research Department of the United States Navy Training Research Laboratory has been developing and testing CAI course modules in basic electronics. Course material has been developed in Direct Current Circuit Analysis, Alternating Current, Inductance and Capacitance, AC Series Circuits and Resonance, and AC Parallel Circuits and Resonance. An IBM 1130-based 1500 Instructional System with 15 instructional terminals is used to present the material. Each terminal is equipped with an audio unit, CRT with light pen, an image projector, and a keyboard. IBM COURSEWRITER II is used for the CAI programming language. This system presents the electronics course modules as tutorial sequences interspersed with problem solving and simulation exercises.

The project has developed and tested a variety of instructional strategies. Dr. John Ford, Jr., director of the project, describes two ways the term instructional strategy is used to describe the training presented.

> First, it refers to the sequence or flow of instruction for a training objective. This is a more global strategy and encompasses many instructional presentations or "frames." In the second usage, the term refers to techniques used within an instructional frame. In this latter sense, we are explaining many methods of bringing student responses under stimulus control and of various types of feedback (Ford, 1970).

In evaluating the results of one of the CAI modules, it was found that those students trained in using CAI methods scored significantly higher when tested on the CAI material than did the control group. A time saving of from 33 to 44 percent was also realized by use of the CAI modules. Student reactions to the CAI training was also very favorable. Ford (1970) summarized some of the additional results of the project as follows:

> In addition to evaluating the quality of CAI in achieving training objectives, a better understanding has been gained of the type of learning environment which is afforded in this CAI system and of the system characteristics needed to support a research and development project in CAI. A CAI system is an extremely powerful tool for discovering and analyzing learning problems of individuals and groups of trainees. The effects of a training method are made brutally obvious down to the fine grain step-by-step training sequence. First, student performance records are examined to determine whether the behavior was learned during the training sequence. Next, a check is made on the amount of practice which was provided. Then, test performance is examined to determine the longer term effects of training. In this way, the causes of ineffective training can be identified and related to specific training events. Also, the effects of different instructional strategies can be assessed much more accurately than before. Self-pacing has proved to be a very effective technique for optimizing training achievement . . . .
>
> There is a growing emphasis today on developing CAI capabilities which can provide significant amounts of education or training for a given program. Although there are problems, the potential for achieving this goal looks good. Some of the pioneering work in CAI focused upon research in learning and instruction. We are beginning to realize or perhaps re-discover, how powerful a tool a CAI system can be for such research.

Other Navy Programs

In addition to the project at the Training Research Laboratory at San Diego, the Navy is developing a Computer-Managed Instructional system in the Naval Air Technical Training Command at Memphis, Tennessee. In this system, the computer administers the instructional process, but does not take part in the actual instruction. The United States Naval Academy also uses an IBM 1500 Instructional System to help teach credit courses in Russian, thermodynamics, physics, and fluid dynamics. The system also serves as a research tool to help shape the Academy's approach to computer-assisted instruction.

These projects demonstrate the interest in the application of the computer to instruction on the part of the training establishment of the Navy.

Stanford University Program in Computer-Assisted Instruction

The Institute for Mathematical Studies in the Social Sciences began a research and development program in computer-assisted instruction in January 1963, under the direction of Dr. Patrick Suppes. Two basic approaches to computer-assisted instruction are followed by the Institute: drill and practice, and tutorial. The tutorial approach to CAI uses the computer as a "teacher" to present new concepts as well as to determine subsequent student work with the concepts. In contrast, drill and practice systems supplement classroom instruction by improving the skills and concepts introduced by the classroom teacher (Suppes, Loftus , & Jerman, 1969). The institute has developed drill and practice programs in mathematics, reading, and spelling for elementary school age children. Tutorial programs in elementary mathematics, reading, logic/algebra, and two years of college-level Russian have also been developed by the Institute.

The tutorial Russian program provides comprehension of spoken and written Russian as well as training in grammar and syntax. The Russian language program uses a teletype terminal with a Cyrillic keyboard and computer-controlled audio tapes recorded by a Russian language lecturer. The computer system, which provides all regular classroom instruction, has been very successful. Computer-based instruction in languages appears to have great potential at the secondary and college level.

The computer complex used by the institute utilizes a Digital Equipment Corporation PDP-1, PDP-8, and a PDP-10 with 192K words of Ampex core storage, two IBM 2314 disk files, two 2401-4 tape drives (1600 bytes per inch), and a 2803 tape control unit. The system is currently driving up to 150 teletype terminals. Philco Ford "READ," CRT consoles are used for curriculum development and course revision.

An important facet in the development of the Stanford CAI project is the data analysis and research activity relating to curriculum development and the development and testing of instructional strategies expressed as mathematical models. The use of CAI as a tool in educational research has been clearly shown to be a major contribution.

> Before the advent of computers, it was extremely difficult to collect systematic data on how children succeed in the process of learning a given subject . . . . . A computer can provide daily information about how students are performing on each part of the curriculum as it is presented, making it possible to evaluate not only individual pages, but also individual exercises (Suppes, 1966).

Evaluation of the effectiveness of the Stanford CAI program has shown significant gains in student achievement in the three years the system has been used in an operating school environment. A comprehensive evaluation of the mathematics and Russian language programs points out the difficulties in providing a "hard data" evaluation of CAI programs (Suppes & Morningstar, 1969).

Atkinson and Wilson (1968) also comment on the inherent complexities of evaluation of CAI programs:

> Evaluation of a computer assisted instruction program is only partially an evaluation of the system and equipment. Primarily, it is an evaluation of the instructional program and as such is basically an evaluation of the program designer who is the real teacher in a computer-assisted instruction system. The evaluation question then becomes, "to what extent did the curriculum designer provide the computer with an appropriate set of instructional materials and an adequate decision structure for branching among them?"

This same article also points out that measuring effectiveness of CAI is also difficult because of a "current lack of a sound theoretical basis for describing levels of learning and achievement."

The Stanford CAI project has developed a unique approach to the course design in both the elementary mathematics and reading programs. The course context is divided into "strands" which are defined as basic component skills. The student's instruction is individualized as he progresses through the various strands based on his performance. The mathematics curriculum has 15 strands, and the reading program has six strands. Progress within a strand is based on performance criteria in that a student goes on to a new exercise only after successful completion of the current exercise. A reporting system provides the teacher with the individual status of each student in each strand and a status report for the entire class. This report assists the teacher in providing remedial work and determining areas requiring additional emphasis.

Another application of the drill and practice mathematics program is a project in the New York schools called "Dial a Drill." Using a touch-tone telephone receiver as a terminal, 2,400 student can receive automated arithmetic drills. The students receive three 5-minute drills per week that are automatically adjusted by the computer

to the level at which the student can perform successfully. The project is demonstrating the potential of CAI in providing instruction in basic skills using a very low-cost terminal.

This brief summary of the Stanford CAI project shows the progress that has been made from its modest beginning to a 150-terminal system serving schools located in six states and the District of Columbia.

The University of Pittsburgh Learning Research and Development Center

The Learning Research and Development Center was established at the University of Pittsburgh in April 1964. The general purpose of the Center is the

> . . . . scientific study of the problems of learning and instruction with particular attention to the nature of the educational and psychological environment required to maximize the potential of the individual learner. The broad goals of the Center are the following: (1) To contribute to the growth of those aspects of behavioral science which are relevant to educational practice. (2) To develop prototype models of instructional procedures and appropriate hardware and software through the involvement of scientists, engineers, and educators. (3) To develop and evaluate experimental instructional systems, including materials, procedural components and personnel training (Yeager & Glaser, 1968).

The center is currently conducting exploratory research projects in stimulus control, learning strategies, memory, and psycholinguistics. This research is centered in the Basic Learning Studies Program. The CAI program is concerned with the "analysis of learning processes as students work in partially automated environments, the design of experimental student stations, the study and development of effective CAI courses and the evaluation of the potential role of CAI in a range of educational applications (Yeager & Glaser, 1968)."

The center has experimented with the use of touch-sensitive display, audio and visual access devices, and CRT displays. Much effort has also gone into research efforts concerned with the use of the computer in the management of the educational process. Ferguson (1970) points out the services that the computer can provide in this area: (*a*) collection and storage of data, (*b*) information retrieval, (*c*) testing, (*d*) instructional planning, and (*e*) instruction.

A pilot project at the Oakleaf School in suburban Pittsburgh involves an educational data system for both classroom management and research purposes. The system uses an IBM 360 Model 50 computer located at the University Computer Center, an optical scanner, a card punch/card reader, and a typewriter console at the school. A typewriter terminal at the Learning Center also provides access to the research data for the project staff. The system allows the classroom teacher on-line (over telephone lines) rapid access to student instructional management data. The feedback of information on the instructional operation at the school is being used to improve student performance. The computer provides a data storage and analysis capability that would not be feasible by any other means.

Results of this project and studies of Computer-Assisted Testing (CAT) and Computer-Assisted Instruction (CAI) have resulted in another project involving a small local computer at a school. The proposed terminal configuration includes teletypes and cathode ray tubes. The project will test the hypothesis that "a small computer can support educational management, computer testing, and some CAI lessons (Ferguson, 1970)."

Another of the center's major programs is Individualization of Education. One of the principal projects in this area has been the development of a system called Individually Prescribed Instruction (IPI). The system is designed to provide instruction tailored to a student's individual abilities and needs. The system was first operated in the Oakleaf School in 1964 and is now being used by 160 schools in 32 states. The system provides instructional materials in elementary mathematics, reading, science, handwriting, and spelling. The system was originally nonautomated, but a computer-based management information system was added to facilitate collection of data for system improvement and analysis. The IPI system is based on an instructional model described as a sequence of operations as follows:

> (1) The goals of learning are specified in terms of observable student behavior and the conditions under which this behavior is to be manifested. (2) When the learner begins a particular course of instruction, his initial capabilities – those relevant to the forthcoming instruction – are assessed. (3) Educational alternatives suited to the student's initial capabilities are presented to him. The student selects or is assigned one of these alternatives. (4) The student's performance is monitored and continuously assessed as he learns. (5) Instruction proceeds as a function of the relationship between measures of student performance, available instructional alternatives, and

criteria of competence. (6) As instruction proceeds, data are generated for monitoring and improving the instructional system (Cooley & Glaser, 1969).

Exploratory research and development is also being conducted in the use of computers in secondary schools. The program proposes a variety of hands-on experience for both teacher and students. The experiment will explore the applicability of a general "computer-activated learning" model, develop a supportive structure for the application, and develop specifications for a controlled dissemination program.

The work of the center has been summarized in what the faculty considers the

> . . . .themes of investigation which are of special significance to research and development relevant in education. These themes are the following: (1) The importance of contact with scientists, engineers and subject matter scholars and the mutual interplay between basic and developmental activities so that a body of technology can be made available for the design of educational practices. (2) The importance of adapting educational environments to the requirements and requests of the individual learner. (3) The significance of evaluation not only for the assessment of student progress in the course of his education, but also for the monitoring of educational procedures and materials in order to redesign and improve them, and to put their respective contributions to the educational process into the proper perspective (Yeager & Glaser, 1968).

Computer Terminal and Visual Display Devices

Another important aspect of this survey was collection of data on the type of readable (character display) terminals available for use in computer-based instruction. This was of immediate concern since character terminals would be the first used in the system, and since most character terminals are easily interfaced. The primary information which was sought were the parameters of cost, display speed, ease of interfacing, noise, and legibility. While information is available in all other parameters, no information was found on legibility although observed terminals were found to differ visibly in this respect.

The following section summarizes characteristics of each family of terminals although it may identify the class by a particular brand name of terminal. This is not an endorsement of any particular terminal over other terminals, but is used to improve identification of the class by mentioning more commonly seen devices.

Since the visual information given to a student normally contains a greater amount of information than any other sensory input, it is important that this input be quite readable and thus not easily tire the student. Equally important, since a great deal of information will be presented over the terminal device, its operation must not overly tax the computer. Since this part of the system will also be a part of almost every student terminal, it must also be reasonably priced with respect to its performance.

There are many different ideas about what device constitutes a perfect terminal; in most cases, the differences of opinion are legitimate. There was, however, no evidence of a careful experimental evaluation of a number of the different devices along common criteria. Rather, in each case, some particular constraint (e.g., cost, environment, innovation) dictated the particular device to be used.

The devices are discussed in the context of where and how they were used in an educational situation, with an attempt to pinpoint why they were chosen for the situation. Those devices not observed in a CAI application are also described, and probable CAI application is mentioned.

Teletype ASR-33 Terminals

The teletype terminal is undoubtedly the most commonly used terminal device in the country. Constituting the basic terminal in the CAI systems sold by RCA and Hewlett-Packard and some systems sold by IBM, the teletype terminal is probably the least expensive device currently available for sale. Its primary attributes as stated by most users are: (*a*) low cost; (*b*) hard copy output and keyboard; (*c*) ease of interfacing with computers; (*d*) ease of remote use over telephone lines; and (*e*) availability of service.

Similarly, a great number of complaints were found criticizing the device, including: (*a*) high noise level; (*b*) variable reliability; (*c*) slow display of information; and (*d*) lack of graphic capability.

To understand why these terminals were chosen, one needs only to look at their intended use. In the Stanford CAI program, the teletype was selected for use in the elementary school system for administering mathematics and spelling drill and practice (Suppes *et al.*, 1969). In the application, the amount of information to be viewed at one time was limited to several lines, such as a simple math problem or a single line of words to be spelled. In the mathematics drill, the

student was not reading or considering complicated text material, so the background noise generated by several teletype terminals was not considered too great a distraction. Since students were wearing headphones in the spelling drill, the noise in that instance was somewhat attenuated. On the other hand, a silent CRT display might have been desirable, since only small chunks of instructional material were displayed at a time. However, in this case, cost was the overriding factor, since there were 150 terminals in the system. This is the same reason RCA markets the ASR-33 with their Instructional 70 system for similar drill and practice uses.

Similarly, the HP2000A is marketed by Hewlett-Packard with teletype terminals or their plug-to-plug equivalent. It was stated by several manufacturers that a CRT display could be made cost-competitive with teletype displays if sufficient sales volume could be reached to justify a highly automated assembly line. Such a market does not currently exist, however.

Dot Matrix CRT Displays

The dot matrix CRT display was found in only one CAI system as a student terminal—the IBM 1500 system. This particular CRT allows not only character display, but also has a limited graphics capability. Lines which may be drawn as a trail of dots on the screen are adequate for low-resolution display of data. The screen image is actually generated by a raster scan technique, but the raster is one of point-addressable dots. Although the display is legible, it is more difficult to read than most digitized television displays, and is prone to a slight flicker and jitter (vertical vibration).

The 1502 CRT includes a light pen device which allows the student to touch the screen with a probe. The CAI program can establish programmed meaning to locations on the screen and thus determine if the student touched one of the meaningful locations.

The 1502 CRT was introduced as the terminal device in the 1500 system in order to obtain feedback from its users which IBM could use to consider the design of a next generation CAI system. At this time, no such improved machine has been produced, and the 1502 CRT is neither manufactured for nor supported by the 360 series of IBM computers.

The attributes of the 1502 CRT as stated by IBM are: (*a*) very rapid display of information; (*b*) graphics capability; (*c*) light pen; (*d*) high performance per cost in 1500 context; and (*e*) silent operation. The disadvantages are: (*a*) no hard copy; (*b*) video disk unit required to refresh display so no telephone lines can be used between computer and terminal; and (*c*) less than perfect visual display could be tiring if much text were displayed.

This display device was chosen by IBM rather than by the system purchasers, since it was to be an IBM research and development device. Therefore, the applications did not always reflect appropriate use of this CRT in the way that other applications directed the purchase of teletypes. One exemplary use of the system at Fort Monmouth and at the Navy Electronics School in San Diego is the experimental teaching of a block of basic electronics on the 1500 system. In this context, the CRT is used as a text and question display device and as a light pen or keyboard response device. There is nothing in this type of usage which definitely requires CRT or light pen use, but the devices are being used experimentally, since they are included in the current 1500 system configuration.

In a statistics teaching program at Florida State University, the graphics ability of the scope is used to display statistical distributions generated in the CAI package as examples of the statistical distribution types being explained to the students. Implementation of APL as the computer language allows graphical display of results of computations, but does not support light pen use.

IBM 2250 Vector Display Scope

The IBM 2250 vector display is marketed by IBM for use with the 360 series of computers as a graphics display device. Its display is a set of vectors which can connect any two points on the screen and which are refreshed from core memory by a small controller associated with the 2250 device. The 2250 offers extensive graphics capability, especially in situations where the displayed information must change frequently. While its use as a student terminal is untested, it offers the advantages of: (*a*) graphical versatility; (*b*) rapid display change; and (*c*) large screen size. Its disadvantages, in many ways stemming from its advantages, are considered to be: (*a*) high cost; (*b*) excessive flicker and image instability; and (*c*) poor character display.

The primary observation of the 2250 was in its use in the POGO (*P*rogram-*O*riented *G*raphics *O*peration) graphics system at the Rand Corporation. In this use, as an author graphics device, the user could generate line and figure drawings from a

Rand tablet (a two-dimensional touch-sensing input device) and manipulate their size and orientation on the 2250 screen. In this use, the rapid display changes on the screen were quite useful as was the vector-generated display. The POGO system offers much potential as a device for generating automated graphical displays which could be photographed and displayed on motion picture film. Similarly, it could be used to construct schematics and hydraulic diagrams, or logic, PERT, or flow charts, all of which require the type of graphics offered in the 2250.

The use of the 2250 as a student terminal would have to be considered quite carefully as the cost of the terminal and computer support required is high in comparison to the support required in teletype terminals. There are several other types of vector displays available, notably from the ADAGE Corporation, but these devices are also quite expensive and require computer mainframe support of some type. Technology is thus available for graphic display of information, but the cost involved is an overriding factor in applications not absolutely requiring the dynamic terminal.

Digitized Television Display (CRT Terminal)

Digitized television is a basic technique and comes in many variants depending on the exact use of the device of which it is a part. A digitized TV display could appear as an array of characters similar to the dot matrix display, as a dot graphic display, as a bilevel (black and white areas only) picture, or as a normal TV picture with gray tones as well as black and white areas. The technique of using raster lines to compose characters is the basis of 20 to 25 terminal devices recently introduced for use with computers. In these devices, typically, the set of characters to be displayed is transferred to and stored in the terminal in MOS (metal-oxide semiconductor) memory devices from which the display is hardware refreshed. These devices are all plug compatible with teletype units so they can be used interchangeably with ASR-33 units. Their display change speeds can generally be adjusted from teletype speeds up to 100 times teletype speeds, and some terminals offer storage of several screens full of characters within the terminal. Prices range from approximately $1,500 for 32 by 12 character displays up to $5,000 for 60 by 24 by 4-page displays.

The primary advantages for this type of display are: (*a*) no refreshing required from computer; (*b*) teletype compatibility and telephone line connection; (*c*) silent operation; and (*d*) highly legible display with very little jitter and no flicker. These advantages are again weighted against the typical disadvantages of: (*a*) higher cost than teletype terminals; (*b*) no hard copy; and (*c*) no graphic capability. No CAI uses of this type of terminal were observed. Several facilities using teletypes expressed a desire (but not the necessity) to use this type of terminal to replace existing teletype units; they did not do so because of the higher cost. Although the basic terminal can not display any different type of information than that displayed by means of a teletype terminal, it has the advantage of silent and faster display generation. These devices should probably be compared in an educational stituation to determine when the advantages of speed and silence would justify the additional cost of the CRT terminal.

Digitized Television Driver

This unit is really a variant of the digitized television display. Rather than building a separate character generator, memory, and keyboard, a television monitor or home TV set is used as the display device. The digital driver simply connects to the monitor or sweep circuit of the home TV and acts as an interface to the storage device or computer which is generating the raster. Typically, a video disk is used to furnish the raster; the display driver may contain a character generator to make the display look like the display of the digital terminal. These devices are sometimes useful in applications where a large number of identical displays are needed. The advantages are: (*a*) low cost when multiple, identical displays are needed; and (*b*) silent display. However, the disadvantages are: (*a*) high cost of video disk; (*b*) displays must be located near driver; (*c*) TV tubes must be augmented by keyboards for use as terminals; and (*d*) non-character display rasters require a great quantity of storage.

Although none of these systems were observed, a system based on this technology is being developed by the Mitre Corporation. Mitre bases estimates of the system's low operating cost on the economy of size (10,000 terminal system) and on low cost of the computers used as simple storage/retrieval devices for the television rasters. The system limitations which have been noted are not considered serious since the system was designed as a presentation device for use in elementary school systems where the information is primarily text display to the students.

Direct View Storage Tubes (DVST)

The direct view storage tube is an outgrowth of oscilloscope and storage device technology which

has only recently been in use in CAI systems. The observed usage of the device was in a computational assistance system programmed as background processing on a 360-75 at the University of California at Santa Barbara (UCSB). The DVST was used as the output device in the system and was interfaced to the 360-75 by hardware built at UCSB. The DVST, built by Tektronix Corporation, has a 4 by 4 inch viewing surface upon which either characters or any graphics information may be displayed. While the screen does have addressable points, the display is drawn with continuous vectors. This device provided the highest quality display observed both for graphics and for legibility.

The DVST requires no computer refresh since image persistence is obtained by the physical characteristics of the DVST. This same characteristic results in an image which is totally free of flicker and jitter. The only drawback is that it is best viewed in a dimly illuminated room. Character generators at UCSB were located in the interface unit and shared among 32 terminals, but the character display may be generated as a dot matrix or line vectors, and may be generated either by computer software or terminal hardware as desired. At that time, the price of the basic tube was about $600, with UCSB figuring the price of each student terminal plus interfacing and 128-character keyboard at about $1,200. Tektronix has since introduced a larger 16 by 21 cm DVST at a cost of $2,500. This DVST could be used either as a large student terminal or as an author graphics terminal with POGO type software. The advantages of the DVST are: (*a*) low cost in 4 by 4 inch size; (*b*) flicker and jitter free display; (*c*) no refresh required; (*d*) highly legible display; (*e*) graphics capability; and (*f*) silent display. The disadvantages of the DVST are: (*a*) no hard copy; (*b*) dim lighting or screen hood required for viewing; and (*c*) must be augmented by keyboard and interface to computer.

In the context of the UCSB system, the DVST is an excellent output device since it is a student terminal with graphics and does not require a special purpose driving system such as the IBM 1502 scope on the 1500 system. Since student terminals are all located within a reasonable proximity of the main computer, no special lines are required, and the terminals are compatible with voice grade telephone lines. The UCSB system drives 16 terminals located at various locations around the United States and a total of about 45 terminals at UCSB, all of the DVST type. Since the terminals are silent, many can be located in the same room without the problem of noise interference from nearby terminals.

Computer-Controlled Optical Projectors

A computer-controlled optical projector consists of some type of film media (such as strip, slide, or microfiche), an indexing mechanism, and a projection screen. The types observed were a strip and slide projection device and an indexible projector. There have been many indexible film devices, but probably the first under computer control was the projector available as part of the IBM 1500 system. The programmer could programmatically select individual frames to display to the student and ask questions or present text on the adjacent 1502 CRT terminal. No light pen type device was available for the projector, but it was possible to augment the presentation with visual displays. The major advantages in this type of device are: (*a*) presentation of photographic information; (*b*) presentation of color coded information; and (*c*) local storage of photographic material. The disadvantages are: (*a*) difficulty of preparation of course material; (*b*) difficulty of alteration of course material; and (*c*) difficulty of changing material at terminals.

These devices were observed only in experimental use at the Navy Electronics School in the course in basic electronics. The slides augmented the programmed instruction being presented on the 1500 system.

Addressable Projection Display

The addressable projection device with light pen is essentially a frame-selectable, cartridge-loading projector, with a probe that the student can point at program-addressable places on the projected display. This means that photographs, photographed wiring, hydraulic diagrams, or photographed devices could be displayed to a student, and the student could input to the computer either questions or answers about specific places in the device. While this device was not observed in operation in a CAI system, it has obvious advantages over CRT displays for certain applications: (*a*) information may be graphics, characters, or photographs of actual devices; and (*b*) student inputs in two-dimensional language (i.e., a place on the screen) rather than with verbal response. Weighed against these advantages, there are the considerations that: (*a*) film must be loaded at device rather than at computer; (*b*) no hard copy; and (*c*) must be augmented by some other terminal device with keyboard.

This is not a terminal by itself but is, rather, a different type of input/output device and should be considered as an addition to rather than a substitution for the normal terminal. The device is marketed by IBM and is compatible to their 360 series of computers.

Owens-Corning Photosensitive Glass Terminal

This terminal is a new device based on new glass technology. Its display medium is a glass plate which is sensitive to ultraviolet and infrared light. Upon exposure to ultraviolet light, the glass darkens and may be made transparent again by exposure to infrared light. The device is functionally similar to the direct view storage tube in that either graphic or alphameric information may be displayed on the tube, and the image remains until the entire screen is erased by exposure to infrared light. Unlike the direct view storage tube, nothing can be displayed without putting it permanently on the tube. To show something temporarily, it must be added to the display. To erase the temporary addition, the entire screen must be erased, and all but the temporary addition must be redrawn.

The advantages of this device are primarily the advantages of the DVST except for the fact that a hard-copy device is built into the terminal, and the price is about $19,000. The advantages enumerated are: (*a*) hard copy output; (*b*) silent operation; (*c*) rapid change of contents of screen; (*d*) graphic capability; (*e*) no refresh required from computer; (*f*) highly legible display; and (*g*) flicker- and jitter-free image.

The terminal was very recently introduced and has not been observed in any CAI system. While the device offers many potential uses as a terminal in a system requiring graphic capability, the cost is quite high for consideration as a student terminal. No information was initially released regarding the interfacing of the device with telephone lines.

Portable Printing Terminals

The portable printing terminals are a group of terminals which are very similar to teletype units in function. They consist of a keyboard usually compatible with the ASCII coded teletype-character set and a printing device, usually a wire matrix rather than an impact printer. The wire matrix printing unit allows a reduction in weight and noise of the unit and results in a package that weighs typically under 30 pounds. An acoustic coupler is built into the unit which allows it to be used with any common telephone.

The major advantage of this unit is portability which allows it to be taken wherever the terminal is needed. The unit can be used as a nonportable unit, and the acoustic coupler avoids the cost of a dataphone while allowing the terminal to be used at an individual's desk through normal telephones. The only disadvantage of the device in this application (compared to a teletype) is that it is more expensive than teletype and usually requires heat-sensitive paper as compared to the very low-quality, low-cost paper required by the teletype. This terminal's advantages are: (*a*) portability; (*b*) compatibility with telephone lines; (*c*) low noise operation; and (*d*) hard copy. Its disadvantages are: (*a*) higher cost relative to teletype; and (*b*) special paper required.

These units were all recently introduced and offer minimal advantages in the typical CAI classroom consisting of fixed terminals. The portability of the device is useful where a student must be taken to some large, possibly immobile training device. Perhaps the application of the portable terminal as an author terminal, which can go to the author as opposed to the author going to the terminal, offers the most effective use of the author.

Portable CRT Terminals

The portable CRT is a recent development analogous to the portable printing terminal. It offers the same advantages to a fixed CRT as the portable printer offers to the teletype user. The additional advantages over the fixed CRT are: (*a*) portability; and (*b*) compatibility to telephone lines.

The disadvantage is higher cost than a fixed CRT, part of which is the acoustic coupler cost. For the same reason that portable printing devices have not found their way into CAI applications, the portable CRTs have also not been used. The same potential advantages are present as for portable printers, but they have not yet been exploited.

Color CRT Displays

The color CRT offers a quite recent and inevitable extension to CRT technology. In addition to normal alphameric display in black and white, current color CRTs have the ability to display characters in (typically) eight colors, or as black

characters on a colored background. The addition of color to the display is seen as an advantage when the terminal is used to input data or to monitor operations which require quick operator attention. It is difficult to estimate the value of color display in a CAI application. Since the display tube used in these color displays is a dot-matrix shadow-mask tube of the type used in home color receivers, the display suffers from the same lack of resolution characterized by small-screen color television.

The advantage of the color CRT over the black and white CRT is simply the ability to display color characters. The disadvantages are: (*a*) higher cost; (*b*) lower resolution in display; (*c*) loss of direct teletype compatibility; and (*d*) unknown value in CAI applications.

This device was not observed in any CAI applications and does not appear to have been used in any to this time. These devices were apparently introduced as data entry terminals and thus do not feature very large screens and are limited in the number of characters they display simultaneously. Refreshing information is stored in the terminal, so no computer-generated refreshing is required. The keyboard is usually teletype compatible, but the use of the color capability requires that additional information be sent to the terminal to specify the color of the displayed text.

Computer-Controlled Speech

In certain applications it is desirable to augment a verbal or visual presentation with audio information. The devices discussed in this section are used to generate the audio presentation which is made to the student. Some of these devices do not interface to the computer as plug-in units but instead require direct computer time to produce sound from stored information. Other devices are merely switched on or off by the student or by the computer. All are concerned with audio presentation of information.

Computer-Controlled Sequential Tape

The basic design of this device is a tape recorder which can be started and stopped by a computer program. The computer program presents a section of tape to the student, and then asks him a question either orally or on a teletype unit. The computer then corrects his response if needed and possibly repeats the question or adds additional material until the student responds correctly. In any case, the student goes to the next sequential unit of sound on the tape. Thus the computer is used to receive responses, correct mistakes, keep an item score and student score internally, and control the rate of the presentation. Use of audio brings in an additional sense (hearing), commands attention (the student must listen at presentation rate and must be alert), and allows lecture-like material to be presented at any time of the day; illness or temporary interruptions of the course do not cause the student to miss any of the course material. Every student answers every question presented in the course. The student is immediately corrected if wrong.

The validity of this type of presentation has been demonstrated in a two-year Russian language course offered for credit at Stanford University by Mrs. Elise Belenky. Comparison of student performance in lecture courses as compared to the computer-administered lecture course shows a 40 percent reduction in dropout rates (based on 30-student classes) and far superior performance on paper-and-pencil tests administered to both groups. The improvement is due in no small part to the quality of the material which has been refined and developed over a three-year period by Mrs. Belenky. The permanence of the presentation once developed ensures that good material is preserved while bad material can be easily changed. The nature of this system makes it excellent for languages, but it also applies to any information which can be presented verbally in a lecture. There is also a possibility of using any type of film projector, also computer-controlled, to augment the audio material and a very inexpensive device to respond to the computer, a touch-tone phone. If the system could be combined with a random access audio device, an entire lecture could be presented over a telephone by letting students simply call into the computer on telephones.

Computer-Controlled Random Access Audio Device

This type of device consists of a band of short tapes, disks, or drums which can be easily played in a random order under computer control. This type of equipment, which typically handles phrases or commonly used audio messages, is often used for temporary recordings such as stock quotations, weather messages, and airline flight information. A device of this type might be useful in correcting student responses made on the sequential-type presentation which has been discussed. At the present time, this device apparently is not used by any educational institution. In actual use, this device has characteristics similar to digitized speech.

Digitized Compnter-Composed Speech

Digitized speech has been used by several university and research organizations and, experimentally, by commercial computer corporations. In operation, a computer accesses randomly from a vocabulary of words or phrases stored in computer disk or drum memory. These words are presented as audio information to desired student terminals. Speech is actually stored by taking incoming speech waveforms and sampling their amplitudes at a rate of approximately 30 kc. The resulting amplitudes are compressed to bit strings, and the bit strings are stored on computer disks. By catenating these strings, phrases or sentences can be constructed. Because of the current state of the art with regard to speech quality, digitized speech is probably best used for short responses needed frequently or in a particularly random order.

A system teaching phonetics and spelling to grade school children in the Brentwood School of East Palo Alto, California, makes exclusive use of digitized speech to present material and inform students when they have submitted correct answers through their keyboards. Students wear headphones to isolate their sound from other students and to isolate them from the noise of the teletype terminals they use. Compared to the performance of students taught in conventional manners, superior performance has been shown for students using the system for 10 to 15 minutes a day (Suppes, 1966).

Digital/Mechanical Time-Compressed Speech

Time-compressed speech is normal human speech which has had selective portions of each word and pause removed and the remaining portions catenated together and smoothed. The simplest form of compressor is an electromechanical device which physically chops and then packs information onto a magnetic tape. This device deletes fixed length segments at varying speeds to achieve compression to greater then 50 percent of original length. Although frequency, or tone, does not vary in the process, the rate of presenting the material increases. This both reduces storage requirements for information and decreases the required presentation time of the remaining material.

An alternate approach for time compression is to digitize the speech with a computer and then mechanically discard repetitive subsections of the speech (as described in the preceding paragraph) or delete "redundant" information according to some algorithm. The sound information is most manipulative when in digitized form, but it requires considerably more equipment to process in digitized form. Compression is more or less "free" in any environment which is comprehensive enough to perform digitization of speech since the elimination of substrings of speech is relatively trivial once strings are digitized. Compression of computer storage requirements can reduce considerably the cost of storage equipment for a particular size vocabulary.

Very little work has been done to determine the effectiveness of digitized speech in training, but more general studies have led to the conclusions that it enhances attention by the listener and requires less time to impart a given level of retention. It might be particularly useful for end-of-course reviews or film narration to reduce time and production cost of such materials.

Tonch-Tone Telephone Entry

Touch-tone entry constitutes the cheapest possible type of data entry when the data are to be transmitted over the public telephone network. The touch-tone user first calls the computer by punching in the number to establish the line. From this point, any pushed buttons transmit data to the computer which was called. The computer may also respond to the caller with three tones generated by the receiving unit (Western Electric 403A MODEM), or it may respond with verbal information using any of the techniques which have been described.

Touch-tone entry could be used as a very inexpensive way to administer tests and direct study, dispense information, review courses, or process incoming student data. It could also be used with special texts to teach material to remotely located students, or even to administer language courses as has been indicated. The limited number of responses (buttons) on the pushbutton panel suggests that some uses are more appropriate for full teletype keyboards, but the 10 to 12 button panel is quite adequate for many applications. The IBM 2721 portable audio terminal is an inexpensive extension to any telephone which allows full keyboard input where it is needed.

CAI Languages

After completion of the field trips and collection of literature, all documentation on CAI languages was examined in an attempt to determine the advantages and disadvantages of

languages being used for CAI. This documentation was supplemented by a limited review of manufacturers' literature and professional journal articles describing languages. It was decided to categorize the languages by the purpose for which they were originally intended and then compare them with examples from typical members of each category.

The fundamental purpose of a CAI language is to communicate with a student through a mechanical medium. If the language is incapable of communicating the desired information, the information will either be distorted or will be presented inadequately for learning to occur.

There are many potential types of information which can be displayed; some can be easily handled internally by computer, and some can be easily accessed at the direction of a computer. Upon looking at many of the CAI languages available today, one would probably assume that the only displayable information is typed text and the only reasonably analyzable answers are in such forms as "A," "B," "TRUE," "NO," or a number. From a knowledge of other languages, it appears that minor variations of this information might be obtained, but at the expense of hundreds of hours of author effort for every hour of communication time. It is perhaps reasonable to spend one-hundred hours planning an hour of communication, but once the message has been determined, it should not be necessary to spend a noticeable fraction of the preparation time actually coding the message.

This is not true with some of these languages. Some languages recognize that certain types of material require special devices under program control and, in some cases, simple computations upon the data input obtained from the student. Other languages recognize the need for modularity in order to minimize data transfer with the controlling system. Still other languages reflect the limited capability of the systems which implement them.

For purposes of this discussion, CAI languages are classified into four basic categories. These categories are based on the original purposes of their defining languages rather than the types of material presented when used as CAI languages. After discussion of the categories in general terms, a more detailed description is presented of that one language which best typifies the use of a language from its category in a CAI application.

The four categories have existed for some time and were recognized in a paper by Dr. Charles Frye (Frye, 1968). He notes the following four categories:

Category 1. General Purpose Problem Languages

Category 2. Extended Existing Problem Languages

Category 3. Interactive Terminal-Problem Languages

Category 4. Author-Student Problem-Oriented Languages

Each of these categories can be typified by the following members:

1. PL-1, ALGOL, COBOL, FORTRAN, and LISP
2. SUPER-BASIC, FOIL, and CATO
3. APL, BASIC, QUICKTRAN, and JOSS
4. COURSEWRITER, HONEYWELL AUTHOR LANGUAGE (HAL), PLANIT, DIALOG, and TUTOR

In an attempt to clarify the categories, each is discussed along with a description of one major language within the category.

Category 1. General Purpose Problem Languages. The characteristic of most languages in this category is that they are oriented toward mathematical problem coding with emphasis upon access to typical peripheral devices in computer systems. These languages are most frequently furnished "free" with computers in that their development cost is included in the price of the system. Both FORTRAN and COBOL software are often required for consideration of the system in a government purchase; consequently, they are the most commonly found languages. IBM offers PL-1 for its 360 computers; several other corporations offer ALGOL, the Burroughs version being the most versatile implementation. Since FORTRAN is the language most commonly offered on both large and small computers, it may be considered as typical of this set of languages.

While FORTRAN is ill-suited to CAI applications, it is possible to use it. The basic data structures of FORTRAN do not include "strings" (i.e., groups of characters which may be manipulated by name). FORTRAN implementers have long recognized this flaw, and most working

versions of FORTRAN allow for arrays of data to be initialized as strings (i.e., CAI messages) or to be set to strings by FORTRAN read statements which ignore the non-numeric nature of the data being read into numeric-labeled storage areas. Subroutines may be coded so that through numeric operations the types of operations which are usually done with strings are simulated, providing the program is run on a particular machine with known binary representations of character strings. In particular implementations which allow FORTRAN programs to call assembler language subroutines, it is possible to extend the basic FORTRAN by defining CAI-oriented functions. FORTRAN implementations on machines which support data communications terminals frequently allow these terminals to be used as input/output devices; an interactive situation may thus be established between the FORTRAN program and the student user at the terminal. The following set of FORTRAN statements may be used to provide a comment to a student sitting at a terminal on a 32-bit word, 8-bit byte machine where the terminal is defined as device number 7.

```
INTEGER NOUT (5) /'THE EARTH IS FLAT'/
33 FORMAT ('b', 5A4)
WRITE (7,33) NOUT
```

The message printed to the student would be "THE EARTH IS FLAT." The first statement is used to define the storage area NOUT and to give it the initial value which is the printed message. The second statement is used to define a technique used to arrange and display the message to the student. The third statement causes the display action to be executed and specifies the device, the data arrangement, and the actual data to be shown. This is more complicated than the equivalent statement in COURSEWRITER (i.e., TY THE EARTH IS FLAT) for several reasons:

1. FORTRAN does not assume that a student is the input/output recipient.
2. FORTRAN users often need to explicitly position their output on a page.
3. FORTRAN does not include strings, so the data have to be disguised as an array of integers.

If the author wished to do computation in the program using a student response, he would find it quite easy to do, since computation was the original purpose of FORTRAN. For example:

```
   REAL ANSWER, AREA, R, SAY/'GOOD'/
   ,NONO/'BAD'/
33 FORMAT ('b', 1A4)
13 FORMAT (F3.1)
   R = 3.0
40 R = R + 1.0
50 AREA = 3.14 * R * * 2
   WRITE (7,13) R
   READ (7,13) ANSWER
   IF (ANSWER. EQ. AREA) WRITE (7,33) SAY
   IF (ANSWER. NE. AREA) WRITE (7,33) NONO
   GO TO 40
```

In this example, the author is picking values of radius and is asking the student to calculate the area of a circle. The program computes the correct answer (statement 50) and then compares the correct answer with the student answer received from the terminal. Only one statement is required to do the computation (statement 50), whereas in COURSEWRITER several staatements would be required. If it were desired to keep a record of correct and incorrect answers, a statement such as:

```
   WRITE 78(,43) AREA, ANSWER
43 FORMAT (2F3.1)
```

could be added to write the responses on a file declared as device 78 (perhaps a tape or disk file) which would store both answers each time through the loop.

By the examples given, it should be obvious that some CAI could be done in FORTRAN; however, the things frequently done, reading and writing strings, are a harassment to the author. In addition, the author must be quite familiar with FORTRAN to exploit its capabilities. It is often necessary for the FORTRAN program to be entered through a card reader and compiled in its entirety; thus, an author cannot debug and check his program as it is generated but must build it completely. (Reference to unfurnished material causes syntax errors in FORTRAN.) This could prove to be a source of problems since the course writer would likely be unfamiliar with the material and with computers in general.

The most obvious advantages of FORTRAN are: (*a*) availability; (*b*) ease in performing

arithmetic calculations; and (*c*) accessibility to most computer peripherals.

The many disadvantages for CAI applications are: (*a*) difficulty of expressing string data; (*b*) difficulty in analyzing student responses; (*c*) normal environment of FORTRAN is batch processing so a great deal of core storage may be required for each student; (*d*) programs are normally entered in batch mode rather than from terminals; (*e*) author must be a skilled programmer; and (*f*) courses programmed are difficult to examine and understand since so much data must be disguised to fit into allowable FORTRAN data types.

Category 2. Extended Existing Problem Languages. When a category 1 language is extended to make it easier to use, a category 2 language results. Development of such a language can be shown taking FORTRAN as its base. Suppose the following construct were added to the FORTRAN basic data types:

```
STRING X, Y,
```

and the assignment as well as the write statement were to be modified to refer implicitly to a student terminal. Then the FORTRAN write statement could be added as follows:

```
WRITE 'THE EARTH IS FLAT'
```

or at least

```
X = 'THE EARTH IS FLAT'
WRITE X
```

Similarly, a routine called READNUMBER (X) might be supplied which could accept a student response and treat it as a number, storing it in proper form as a real number X. A function might also be supplied called KEYWORD (A,B) which would be interpreted as true whenever the student response stored as B contained an occurrence of the author-defined string A. The compiler might even be rewritten so that authors could enter each line of the program from a terminal and have a mistake corrected immediately. The implementation could even be modified so that each author or student running a FORTRAN program could share commonly used program routines, reducing the required storage. Languages such as CATO and FOIL are examples of languages based upon FORTRAN which use these types of extensions to increase the basic capabilities of FORTRAN.

There are a number of advantages which arise when a category 1 language is extended to include CAI constructs. A major advantage is the reduced cost of extending an existing compiler as compared with the cost of programming a complete new language. The cost is frequently prohibitive, or sometimes capable people are not available at any price to do the job. The fact that a compiler for the language will probably be furnished with a next machine generation ensures that this starting base will be available if the current machine has to be replaced later.

Another major advantage is that knowledge of the language is generally more common when a popular language is extended. This can result in the easy addition of analysis capability in the language by adaptation of commonly found subroutine libraries already programmed in the starting language. Such a package is obtained from FORTRAN in the Scientific Subroutine Package. This package of matrix handling and statistical routines would be as available in the extension as it was in the type 1 language in which it was originally written.

The primary disadvantages to this technique are those associated with the operating environment of category 1 languages: (*a*) frequently large core storage requirements; and (*b*) programs normally entered in batch mode rather than from a terminal in a conversational manner.

Category 3. Interactive Terminal-Problem Languages. Category 3 languages are defined as interactive terminal languages. The better of these languages attempt to reduce the time required to get a program into operation, as they are used frequently in an environment where expensive scientist time and expensive on-line computer time are both being consumed.

A typical and frequently found example of this type of language is BASIC. The BASIC language is similar in many ways to FORTRAN, but the basic structures have been modified along the following lines:

1. Input/output is easier in BASIC than in FORTRAN.

2. Individual lines of code in BASIC do not interact as much as individual statements in FORTRAN or ALGOL.

3. Strings of characters can be output in BASIC without explicit storage.

4. Computer peripherals are usually not supported by BASIC (although this varies from implementation to implementation).

Since the exact features available in BASIC vary with implementation, BASIC is discussed here in

the context of Hewlett-Packard Time-Sharing BASIC. The normal method of using BASIC is to build a BASIC program in conversational mode with each line checked as it is entered. When the author finishes his program, he may execute it by typing in a RUN command. The program is executed (usually interpretively) until completion, unless it is terminated by error or by the author's pressing of the BREAK key in his console.

An example of a BASIC statement to print the messages shown earlier would be:

```
10 PRINT "THE EARTH IS FLAT"
```

Since BASIC knows the user is at a terminal, it can assume the terminal is the output device, and that the author knows the message will be positioned against the left margin; the need for printed strings was recognized in BASIC. (BASIC was developed many years after FORTRAN and thus did not have to retain compatibility with earlier bad decisions.)

BASIC was also developed as a computation language, so it is not difficult to obtain results similar to those in the FORTRAN example given. The following BASIC sequence can accomplish the same goal:

```
10 FOR R = 3.0 TO R STEP 1.0
20 LET AREA = 3.14 * R↑ 2
30 PRINT R
40 INPUT ANSWER
50 IF ANSWER = AREA THEN 80
60 PRINT "WRONG"
70 GO TO 90
80 PRINT "GOOD"
90 NEXT R
```

It should be noted that this algorithm stated in BASIC is two lines shorter than the FORTRAN algorithm. It is also easier to read than the FORTRAN routine which does the same thing. The readability factor should be considered when material is to be modified by persons other than the original author.

While the format is not ideal for constructing display frames, it entails fewer cryptic coding steps than FORTRAN, and it does perform a drill-and-practice type teaching lesson. If a mistake had been made in entering the program, the author would have been notified immediately, and the error could have been corrected immediately. To check the performance of the material, it can be "run" immediately, so that the author knows quickly whether logical errors have been made. These are definite benefits to the unsophisticated programmer.

The major advantages of BASIC are: (*a*) availability; (*b*) conversational implementation; (*c*) ease of performing arithmetic computations; and (*d*) ease of performing input/output operations.

The major disadvantages of BASIC are: (*a*) difficulty of analyzing student responses; and (*b*) necessity for the author to be reasonably skilled although errors are easier to detect.

Category 4. Author-Student Problem-Oriented Languages. Category 4 languages are those most often billed by manufacturers as "CAI languages" for their systems. Their primary purpose is the construction of frames of information for presentation to the student. In this type of languages, the author is primarily furnishing data which are to be handled in orthodox, standard manners by a program handler and which assume a whole set of conventions for presenting data to students. Typical assumptions in these languages are:

1. Text must be presented for reading by the student.
2. Questions should be multiple-choice, true or false, or based on keywords submitted by the student.
3. Arithmetic to be done is trivial.
4. Computer peripheral support is not available in CAI systems.

Whether these assumptions are valid is determined by the hardware selected and the nature of the course material. If the hardware in the system does not include projectors and sound devices, then constructs to drive them are superfluous. If successful instruction depends on input and display of analog voltages, and the language offers the programmer no access to such devices, then the language is inadequate. Of the various languages fitting category 4, it is safe to say that none of these languages contain all the requirements of a reference language for CAI algorithms.

There is a reasonable variance among the languages in this category. PLANIT and HAL are probably representative of the extremes of flexibility. HAL is an assembler format language which contains virtually no arithmetic capability and must be entered on cards into the computer. PLANIT is a highly conversational language with on-line computation ability and an almost

free-form-decision-frame structure to control branching. In this range of flexibility, COURSEWRITER is more versatile than HAL, less versatile than PLANIT, and probably the most commonly used language due to the IBM 1500 system influence. Because of these characteristics, COURSEWRITER is explained in this section.

COURSEWRITER is an assembler format language in that each author instruction consists of a two-letter mnemonic and an operand list. These mnemonics are used to designate frames of information to display to the student. For example, the statement:

```
RD THE EARTH IS FLAT
```

will display the frame "THE EARTH IS FLAT" to the student and wait until he signals, by typing and response, to continue. If the student should sign off at this point, he will restart here the next time he signs on the machine.

Certain mnemonics are classified as major and others as minor operators. Implicit branching is performed on the basis of these operations. The execution of a major operation such as QU, the question operator, results in all minor operations which follow QU being executed. Thus, in the sequence

```
1 2 QU IS THE EARTH FLAT?            (MAJOR)
1 2 AD 1/ C 5                        (MINOR)
1   CA YES                           (MAJOR)
1   TY VERY GOOD                     (MINOR)
  2 WA NO                            (MAJOR)
  2 TY SORRY, YOU ARE INCORRECT      (MINOR)
1 2 QU IS THE SEA BLUE?
```

the statements labeled "1" would be executed if the student responds "YES" to the first question, and the statements labeled "2" would be executed if the student responds "NO." Notice that in any case the next question is presented. If the student had signed off instead of answering the question, then he would restart the lesson with this question when he next signed on the system. The mnemonics CA, WA signal that their fields, if they match the student answer, are interpreted by the system as (CA) correct or (WA) wrong answer and thus should be recorded accordingly. Note the instruction "AD 1/C5." This instruction adds 1 to the counter C5. Similar constructs exist for subtract, multiply, and divide. Thus, to achieve the simple arithmetic example shown in the FORTRAN example (statement 50), the sequence would be replaced by the following COURSEWRITER sequence:

```
FORTRAN: AREA = 3.14 * R ** 2

COURSEWRITER:

                 COMMENT
SB AREA/AREA     SET AREA TO 0
AD 3.14/AREA     ADD IN 3.14 AS A FACTOR
MP AREA/R        MULTIPLY BY R FOR 3.14 * R
MP AREA/R        MULTIPLY BY R FOR 3.14
                 * R * * 2
```

Thus, the simplicity of expressing text material is easily overshadowed by the complexity of performing arithmetic in an assembler-like manner.

Since the 1500 system included audio and visual devices, certain mnemonics for positioning those devices were included in COURSEWRITER. The "FP" operator positions a peripheral to a selected frame. The addition of a modifier (e.g., "FP(p)") causes the selected frame to be displayed to the student.

Explicit branching is allowed by use of the "BR" branching operation. The branch may be made to any labeled point in the program, i.e., to any frame. It may also be made to implicit return points, such as the last restart point on the last wrong answer return point. The branching may be unconditional or conditional upon numeric tests of counters, switches, or combinations of numeric and switch tests. In this way, the author can "remember" student performance over several frames and control branching on this basis.

Certain other operations exist in COURSEWRITER which allow the author to recognize a sloppy, misspelled, or nearly correct student answer, but most of these are coded as functions which modify the student response before it is compared to the answers given by the author.

The major advantages of a COURSEWRITER type language are: (*a*) ease of displaying written text; (*b*) ease of entry to the system; (*c*) ability to address terminal peripherals such as projectors and tapes; and (*d*) ability to be interpretively executed (low core requirement).

The primary disadvantages are: (*a*) emphasis on verbal information as opposed to arithmetic operations; (*b*) pattern of frame is pre-determined by language rather than at option of writer; and (*c*) low readability since branching and flow is contained in intrinsic attributes of mnemonics rather than explicitly visible in the program code.

It should be mentioned that PLANIT does allow a separation of frame data and branching logic and is more readable as far as program logic is concerned. One unfortunate characteristic of PLANIT is that its complexity almost requires an interpretive implementation; the known examples of PLANIT have been encoded in type 1 languages as interpretive systems in a time-sharing operating environment. PLANIT does represent considerable innovation as compared to COURSEWRITER and should be examined as an example of a high-level author language (Feingold, 1968).

III. CONCLUSIONS AND RECOMMENDATIONS

Terminal Devices

Many useful and sophisticated terminal devices are currently available which would be suitable for use in a computer-based technical training system. Most of these devices can be easily attached to existing computer hardware. Other devices are available which may be useful for collection and display of audio, voltage, temperature, pressure, and electrical waveform, but they are not directly interfaceable to all computer mainframes. For economical use of central processors, and for ease of interfacing, the current best method is to interface nonstandard devices or large collections of input/output devices through small processors called mini-, (midi-, maxi-) computers. Interfacing in this manner enlarges the class of suitable mainframe processors to include most major manufacturers and, in many cases, eliminates the need for special hardware design to perform the interconnection.

Languages

Nonstandard terminals sometimes require special software to make them useful in instructional contexts. A course writer entering material into an instructional system must be able to easily access special devices in his instructional program, particularly while he is collecting data (verbal or otherwise) to be presented to the student. It is unreasonable to expect current software to support input/output devices not yet available on computers. However, it is not unreasonable to expect languages for future instructional systems to interface these new devices so that they are available to course writers; such facilities should be considered in the initial design of such languages.

Another important feature of a course writing language is the ability to support the author in on-line data entry. The language should allow the author to devise nonstandard presentation sequences which can use the unique features available in an advanced computer-based instruction system. By allowing the author to devise new educational strategy and easily implement it, one of the greatest assets of the computer, the ease of changing data, can be of genuine use to the instructor. This very important attribute is not supported in any of the CAI languages which have been described in documentation.

Suggestions for Research

As an initial step in the development of an advanced instructional system, the following steps should be undertaken:

1. Investigation of available mini-computers to determine the best unit for interfacing nonstandard terminals and peripherals to various mainframe hardware.

2. Thorough investigation of terminal characteristics to determine the cost-effectiveness of the various types of terminal devices.

3. Immediate research to design and determine validity of instructional techniques and languages which would become available upon acquisition of a computer-based instructional system.

Step 1 will be undertaken as part of the continuation of this CAI survey project; it should provide specifications for a terminal controller which would make the research in step 2 possible. With the available hardware to perform step 2, it should also be possible to interconnect with a prototype system which would make step 3 possible. The limiting fcactor in the time sequence indicated would probably be the time required to get from the specifications of step 1 to the available equipment of step 2 (i.e., procurement lag time) and from the conclusions of step 2 to the availability of hardware for step 3. At step 3, time delay will depend primarily upon software development time (a function of the system selected and available software for the particular computer). It would be possible to perform steps 2 and 3 simultaneously if adequate funding and flexibility in hardware selection permit the use of adequately programmed and interfaceable mainframes currently available.

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13. ABSTRACT

This paper presents an overview of representative centers active in the research, development, and application of the computer in education and training. Field visits were made to military and civilian agencies in order to obtain a cross-section of various types of applications and research projects. The information presented is based on the field visits and the most recent reports available on the activities of the various centers. Computer terminals used in computer-assisted instruction are discussed, and computer-controlled audio presentation is described. Programming languages which have been used in computer-assisted instruction are categorized, and a typical language from each category is examined.

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